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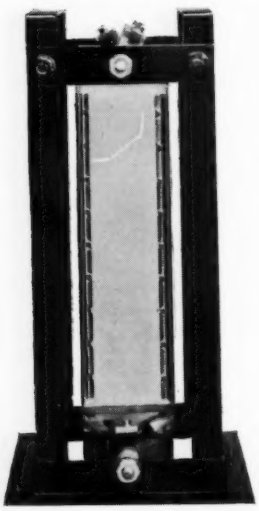

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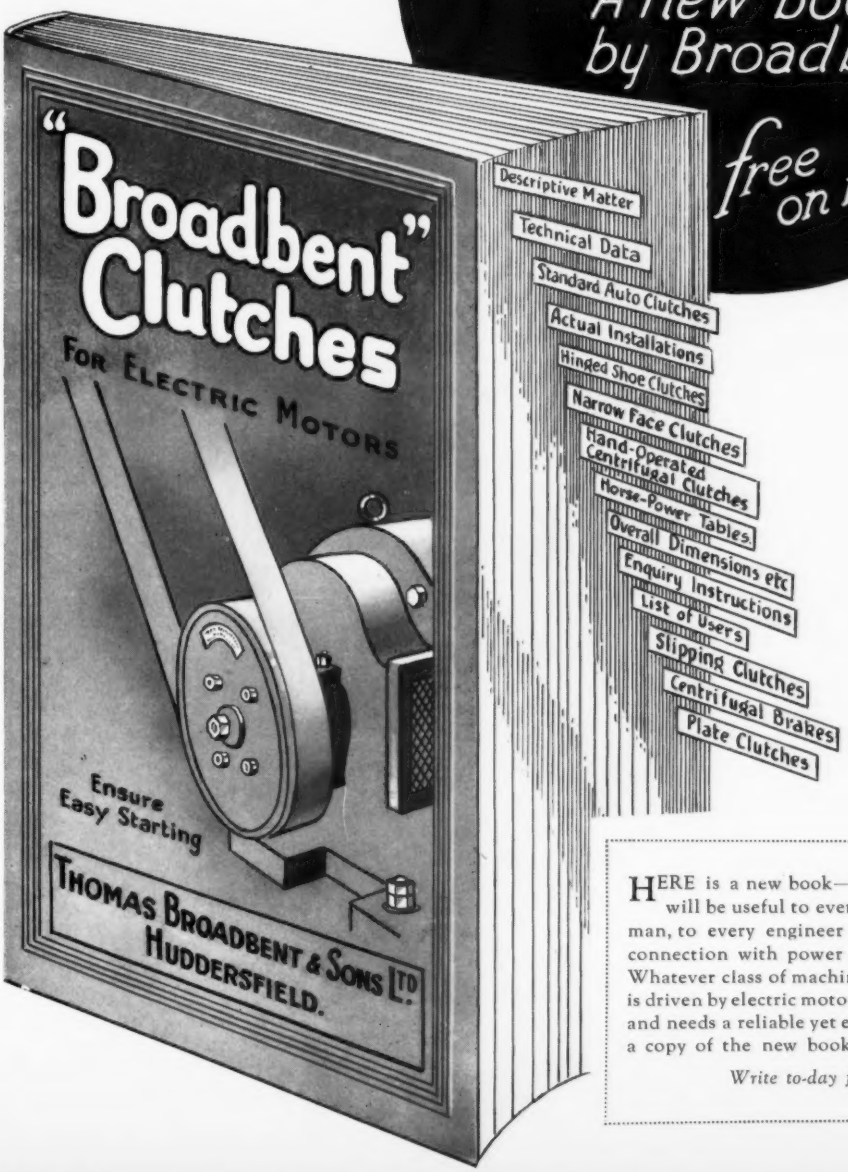

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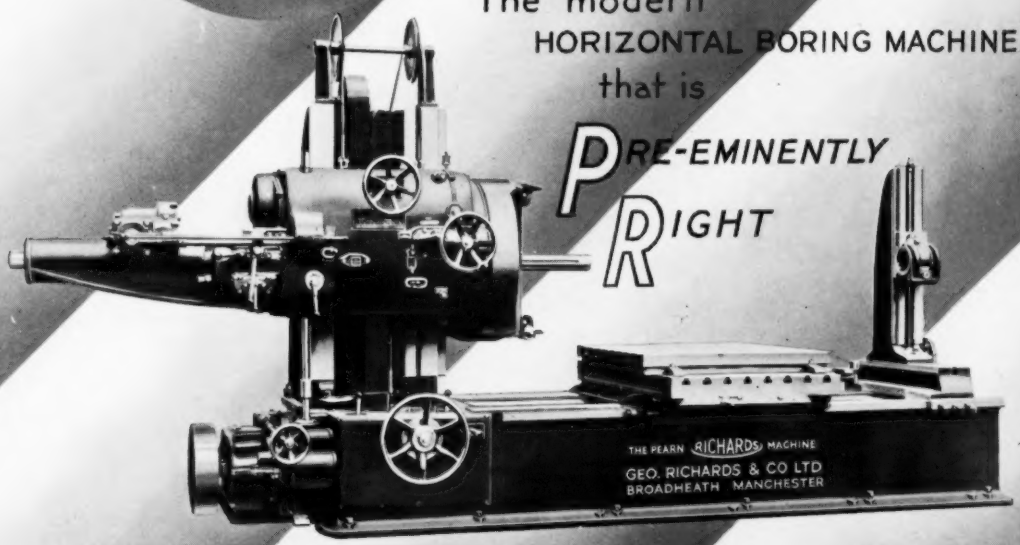

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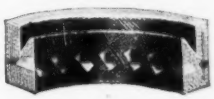

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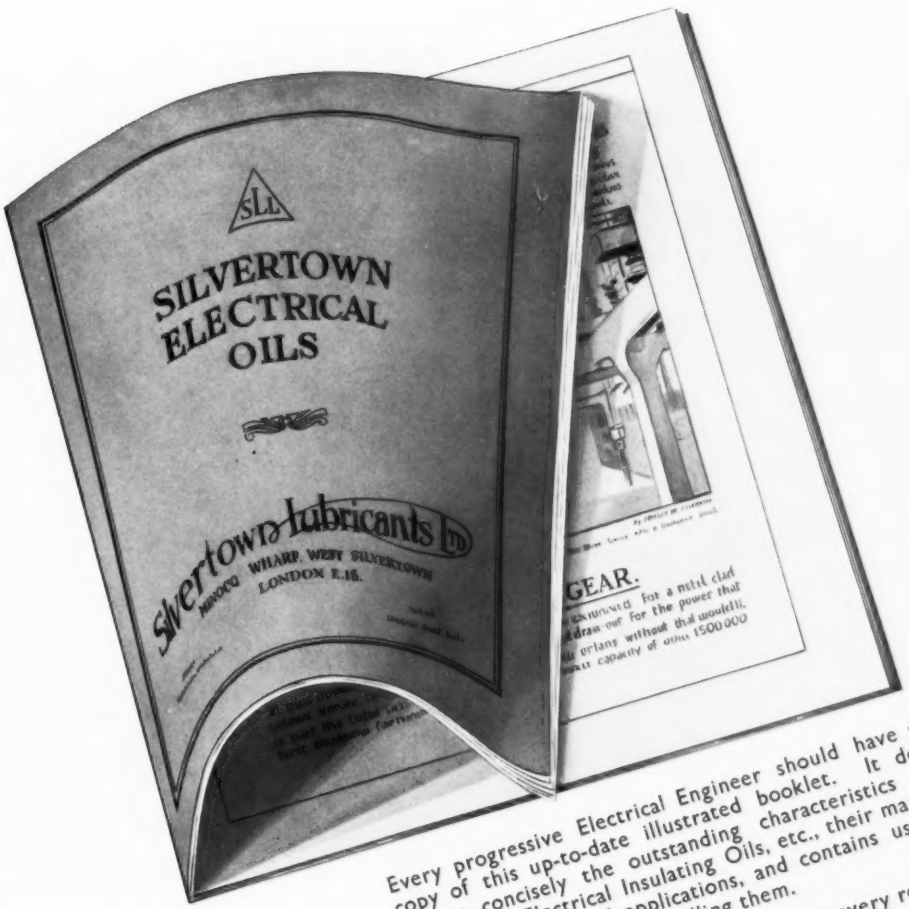

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The English Electric Journal

Vol. VII. No. 1 MARCH, 1934 One Shilling.

CONTENTS.

	PAGE
A Fully Automatic Steel-Tank Rectifier Equipment, Having an Over-Compound Voltage Characteristic -	5
The Trolley Bus as a Public Service Vehicle - - -	13
A Steam Extraction Turbo-Alternator Plant - -	19
200 H.P. Diesel-Electric Rail-Coach Demonstration Run	23

All Communications respecting Editorial Contents should be addressed to The Editor, The English Electric Journal, The English Electric Company Limited, Stafford.

EDITORIAL.

We mentioned in the editorial notes in the December, 1933, issue that further articles on Mercury-Arc Rectifiers would appear from time to time in the pages of this Journal. Accordingly, the first article in this issue is devoted to a description of a fully Automatic Steel-Tank Rectifier Equipment.

The grid-controlled Mercury-Arc Rectifier is particularly suitable for automatic operation, the necessary apparatus being simpler and more reliable than the equivalent required for an automatic sub-station incorporating rotating converting plant.

In an abstract of a Paper given by Mr. L. H. Short before the Institute of Transport at Leeds are set out many advantages of the Trolley Bus as a public service vehicle, especially in cases where

transport undertakings are considering the replacement of existing tramway systems by other forms of transport. It is interesting to note in connection with the proposed extension of Trolley Bus services in London, that the Company, in association with the Associated Equipment Company, Ltd., have received an order from the London Passenger Transport Board for a four-wheel, 60-seater, double deck Trolley Bus. The electrical equipment and body work will be manufactured by The English Electric Company, and the chassis by the A.E.C. This vehicle will be used for obtaining operating experience on the proposed new routes in the Metropolitan area. It may be noted that on the existing Trolley Bus services of the London Passenger Transport Board in Twickenham and district, a large fleet of A.E.C.—English Electric Trolley Buses have been in operation for some considerable time, and have given very satisfactory results.

It has long been recognised as uneconomical to obtain process steam from high-pressure boilers via the medium of a reducing valve. The economies that can be obtained from the use of a steam extraction or pass-out turbine have been taken advantage of by Messrs. John Barker & Co., Ltd., the well-known London Stores and our third article describes the 837 kW. "English Electric" steam extraction turbo-alternator set installed for them. In view of the fact that this plant is located in the basement of a luxury Stores, several interesting features were incorporated in its construction, in order to preserve the amenities of both the building itself and the surrounding property.

The final article gives a brief description of a demonstration run of the Company's 200 H.P. Diesel Electric Rail Coach in which many prominent Railway and Consulting Engineers took part. The rail coach has now completed over 15,000 miles under service conditions.

An Interesting Contract. The Company have secured an important contract from the Thames Steam Tug & Lighterage Co. for a complete Diesel-Electric Tug.

The Tug will be of the barge-handling type and will operate on the River Thames. It will be fitted with pilot house control, and the whole of the equipment will be designed for efficient towing and economical working.

The approximate overall dimensions of the tug are :

Length Overall	...	80 ft.
Breadth Moulded	...	20 ft.
Depth Moulded	...	10 ft. 6 in.

The equipment will consist of two 'English Electric' Diesel-generating sets with auxiliary generators and all the necessary engine room auxiliaries in connection therewith. The propelling motor will be of the double armature type, capable of developing 400 s.h.p. at 100 r.p.m. and will be capable of running at any speed from 0/130 r.p.m. Dead front switchgear will be supplied. The Diesel engines, generators, switchgear and all other electrical equipment will be manufactured at the Rugby and Stafford works, respectively, and the hull will be built by Messrs J. I. Thornycroft & Co., Ltd., Southampton.

A unique feature of this contract is that both the Diesel engines and the electrical equipment will be made by the same Company, thus ensuring complete co-ordination so far as design and responsibility are concerned.

A Fully Automatic Steel-Tank Rectifier Equipment having an Over-Compound Voltage Characteristic.

One of the outstanding features of mercury-arc rectifier equipment is the facility with which it can be arranged for automatic working. Unlike rotating converting plant, which has to be run up to speed and synchronised, before being switched on to the A.C. supply, and has then to be paralleled on the D.C. side before being closed on to the substation busbars, a rectifier installation can be put on load instantly by the mere closing of the E.H.T. circuit breaker. Moreover, as in the mercury-arc rectifier, the transmutation of the electrical energy from the alternating-current to the direct-current form takes place as a direct process; and by means that are entirely statical and non-mechanical, the rectifier presents many other advantages over the rotating convertor—advantages which are by now well known, and to which attention has already been drawn in the pages of this Journal. As the result of these factors, an almost uninterrupted development in the use of mercury-arc rectifier equipment has been taking place, which is culminating in the virtual extinction of rotating converting plant, except for a few special kinds of service. In recent years this development has been accelerated by the introduction of grid control, a new feature in the operation of mercury-arc rectifiers which has been described in detail in the previous issue. By far the most important aspect of grid control is its application to either manual or automatic regulation of the D.C. voltage.

In the case of the 500 kW. steel-tank rectifier equipment at present being installed at the Stuart Road Substation of the Birkenhead Corporation Electricity Department—to a description of which the present article is devoted—the nature of the substation load necessitated a definite over-compounding of the D.C. voltage-characteristic; and of the three principal and alternative ways of meeting this requirement, viz., by no-load tap-changing on the main transformer, by an induction regulator, or by grid control of the rectifier itself, the latter alternative was selected as being not only the most efficient but also the most naturally suited to meet the further requirements that the amount of over-compounding should be adjustable between the limits of 4 per cent. and 8 per cent., the normal figure being 6 per cent.

General Features of the Rectifier Equipment.

The function of this particular equipment is to assist other substation plant, supplying the base load of the 3-wire D.C. system, during times of peak load. Such times are indicated by a fall in voltage at points remote from the main area of supply; so that if additional converting plant situated in such an outlying part of the D.C. system is arranged to start up when a low voltage is experienced there, the equipment will come into service automatically at the desired time.

When the load peak has passed, a time comes when the service of the auxiliary plant is no longer necessary and this condition will be observed by the falling-off in the load on the additional plant, hence the plant is made to shut down when low load occurs.

Almost all systems are subject to momentary fluctuations of load so that it is generally desirable that short time intervals be introduced between the occurrence of the correct starting or stopping conditions on the system, and the actual starting-up or shutting-down of the converting plant, otherwise a number of unnecessary starts and stops are liable to occur. This time-lag feature is incorporated in the equipment to be described.

The general circuit arrangement of the rectifier installation can be seen from the key diagram of connections, Fig. 1. The rectifier is supplied from a 780 kVA. 6-phase fork-connected transformer which presents no unusual features,

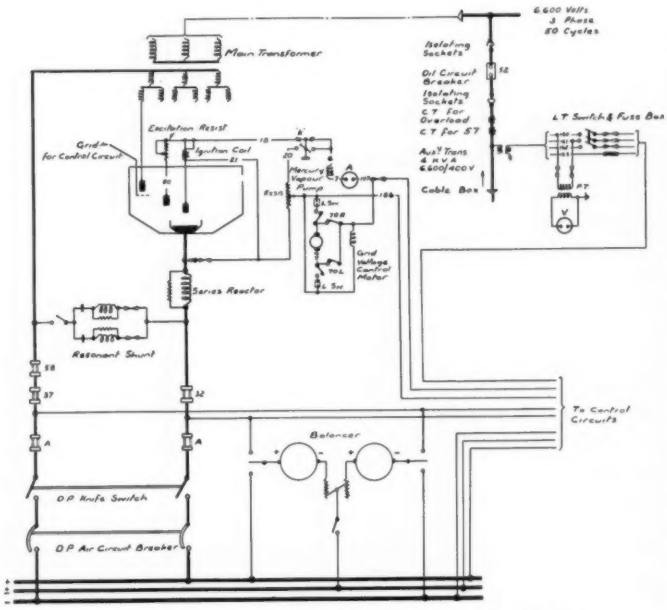


Fig. 1. Key Diagram of the Main A.C. and D.C. Circuits.

except that special tappings are brought out on the secondary side for providing a low voltage during baking-out. The disposition and method of leading-out the several secondary connections is shown in Fig. 2. The usual lightning type auto-valve arrestors are connected across the individual secondary phases to protect the transformer from voltage surges such as may sometimes occur under conditions of low temperature inside the rectifier. On the primary side the transformer is provided with plus and minus $2\frac{1}{2}$ per cent. and 5 per cent. tappings, and is connected to the 6,600 volt, 3 phase, 50-cycle supply through a standard metal clad E.H.T. circuit-breaker which includes a solenoid operated oil switch having a guaranteed safe rupturing capacity of 150,000 kVA. shown in Fig. 3.

The 500 kW. steel-tank rectifier is of normal design and is illustrated in Fig. 4. The general as well as the special features of the " English Electric " design of rectifier have been previously described in the pages of this Journal, and they will, therefore, be alluded to only briefly here. The outstanding feature of the unit is the provision of special control grids, situated in the arc path immediately below the main anodes. The electrical connections to these grids are brought out to suitable terminal flanges insulated from the anode plate, in the same manner as in the case of the main anode-connections. One such insulated grid connection can be seen in the photograph immediately above the thermometer. The customary vacuum-pumping equipment is provided, incorporating a barometric seal which effectively seals off the rectifier from the atmosphere during the shut-down periods of the rotary vacuum-pump. The main cooling water supply is regulated by means of a thermostatically operated inlet valve, while that for the mercury-vapour pumps is allowed to flow continuously.

The D.C. supply for providing ignition and excitation of the rectifier is obtained from a special rectifying unit of the metal-oxide type which at the same time serves to supply the small motor operating the contact-making control disc of the grid-excitation equipment.

Grid-Control Gear.

The grid-excitation system employed for this unit is of the impulse type, giving " hard " control as described in the previous issue of this Journal, and comprises the following main components :—

(*a*) Synchronous motor with shaft extension carrying the brushgear.

(*b*) A contact disc, carried on a spindle, which can be rotated through a small arc.

(*c*) A D.C. operating motor which drives the disc through double-reduction gearing. This motor is reversible, and is controlled by the voltage-regulating relays.

The synchronous motor is coupled electrically to the same source of A.C. supply as the supply to the anodes, and therefore runs synchronously

Fig. 2. 780 kVA. 6-Phase Fork-Connected Transformer.

with the anode voltage. It has a separately excited field which ensures that it pulls into step with correct phase relationship. The field excitation is supplied from a small metal-oxide type rectifier, which is in turn supplied from a small single-phase transformer fed from the same source as the main three-phase winding of the motor. The motor has actually two fields magnetically in quadrature. By varying the relative strength of the two fields the rotor position relative to the stator flux can be varied. In the present case, however, this feature is not employed, and both fields are kept at a constant excitation.

The brushgear on the synchronous motor shaft rotates over countersunk studs on the insulating contact disc. The contacts on the disc are connected one to each of the control grids, and the brush sweeps uniformly over them. The grids are connected by the brushgear to a source of potential which is positive with respect to the cathode. During the period when the grids are not connected to the positive potential they are maintained negative with respect to the cathode. The studs on the disc, and the rotation of the brushgear, are so arranged that the sequence of the positive impulses is the same as the sequence of firing of the anodes.

As the contact disc can be rocked backwards and forwards it is clear that the instant at which the grids are made positive can be made later or earlier in the periods during which the respective anodes are positive and tending to fire ; and as an anode cannot fire until its grid is made positive, although once started, it will continue to burn even if its grid is made negative. Therefore, if

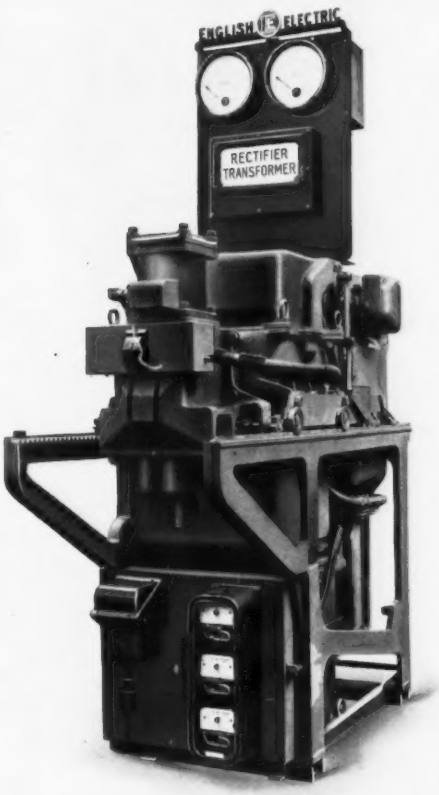


Fig. 3. Metal-clad Oil Circuit Breaker, Type OLD-1A.

Fig. 4. The 500 kW. Steel-Tank Rectifier with Control Grids.

the positive impulse occurs soon enough an anode will fire over the whole of its normal firing period, but if the positive impulse occurs late in the voltage cycle then the anode will fire only from that time to the end of its normal firing time.

The voltage of a rectifier is the mean of the anode voltages over a complete cycle. This mean value is dependent on the maximum anode voltage, the wave shape, and the firing time, and as the two first conditions are constant and the latter can be varied, the voltage can be altered from the maximum to zero by altering the firing time, which in turn is controlled by the position of the contact disc. Now as the position of the contact disc is controlled via the rocking motor and its contactor gear from the voltage-regulating relay, the rectifier voltage can be made to vary as required in accordance with the voltage-regulating relay.

Control Switchgear.

The main control board, shown in Fig. 5, is of the standard slate-fronted flat-back type, and has mounted upon it the relays, contactors, and control switches, necessary to the automatic control of the installation as a whole. It consists of four panels, the first of which (on the extreme right) carries the bulk of the equipment controlling the rectifier auxiliaries, the ignition and excitation supply, and the grid control apparatus.

The chief item on this panel is the automatic vacuum-indicating and control relay, its auxiliary relays, and the constant-current barreter. The movement of the relay is fed from the standard Pirani unit, the detector of which is situated in the vacuum. Above the moving pointer (which moves over a scale calibrated from 0—100 microns) is a chopper-bar, which actuated from an electrically wound clockwork device, chops down at frequent intervals and causes the pointer and a fixed contact attached to it to move downwards. Underneath these are three adjustable contacts each connected to an auxiliary relay. When the pointer is forced down by the chopper-bar it will close any one of the three contacts over which it may be located at the time, which in turn will cause the corresponding auxiliary relay to close.

The three contacts are so situated under the pointer that, the right-hand one will close when the vacuum is high, the middle one when the vacuum is low (but not dangerously low) and the left-hand one when the vacuum is dangerously low (i.e. "soft.") Each of the three auxiliary relays will therefore close under one of the above conditions. The relay which closes when the vacuum is "soft" causes the equipment to be tripped and locked out of service. When the vacuum is slightly below the normal operating condition, the second relay causes the vacuum pumps and their associated auxiliary equipment to start up, when the vacuum is high the third relay shuts down the vacuum pumps.

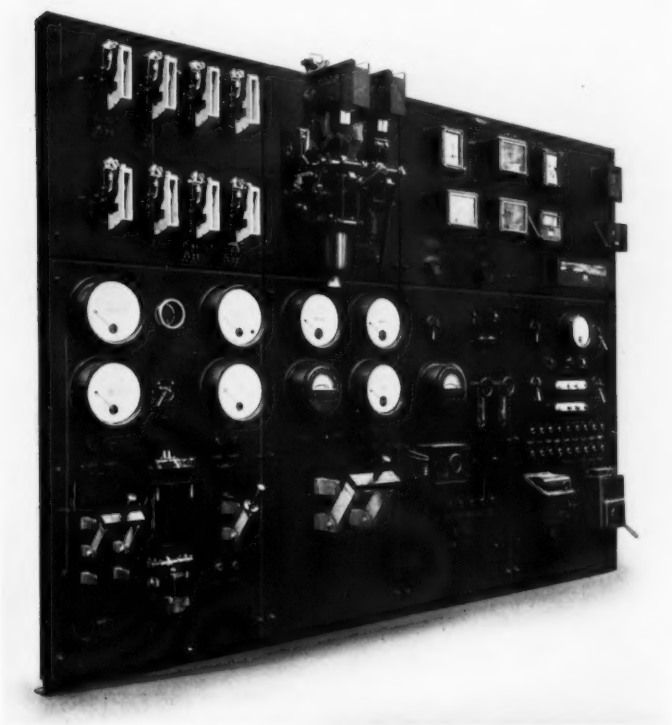


Fig. 5. The Main Control Board.

When the rectifier is in service the two " high " and " low " contacts are made ineffective, as the pumps are then always kept running. The " soft " circuit always remains effective. The vacuum-indicating and control equipment, therefore, ensures that the rectifier vacuum is maintained in a sound condition no matter whether the unit is running or not; or, if this becomes impossible, the equipment is cut out of action, thus preventing the rectifier from attempting to run under conditions of poor vacuum.

At the back of this control panel are mounted the numerous auxiliary items among which may be mentioned the transformer, 3-phase metal-oxide rectifier, and potentiometer supplying the grid bias.

The second panel comprises the equipment for initiating the starting-up and shutting down of the installation, and the voltage-regulating and load-limiting relays whose action is described later.

The third panel carries the main D.C. circuit breaker, isolating switches, and ammeters. The solenoid-operated double-pole circuit-breaker is of the automatically reclosing type, which, on tripping due to an overload or fault, recloses after a time interval which is adjustable. The re-closing gear is set to limit the possible reclosing impulses to a predetermined number after which the breaker remains open and the whole equipment is shut down. Should the breaker remain in for a given time after reclosing for a number of times less than the predetermined number, the counting gear will reset back to give the full number of possible reclosures should a further fault or overload occur.

The fourth panel is equipped with the necessary control gear for automatically starting and protecting the rotary balancer, and also carries ammeters, voltmeters, mid-wire switch and a double-throw double-pole switch by means of which the balancer can be connected either direct to the substation bus-bars or to the rectifier terminals. Normally the balancer is connected to the rectifier terminals.

Automatic Features.

A comprehensive system of protection is incorporated in the automatic control, covering :—

a. A.C. overload.
b. D.C. overload.
c. Failure of A.C. supply.
d. Soft vacuum.
e. Excessive rectifier temperature.
f. Loss of water pressure.
g. D.C. reverse current.
h. Overload on the balancer.
i. Balancer shuts down or fails to start, or is switched out by mistake.

j. Failure of equipment to complete the starting sequence.

k. Failure of the auxiliary supply.

l. Locking-out of the D.C. breaker.

Conditions *a*, *b*, *e*, *f*, *g*, *h*, *i*, *j*, *l*, cause a "lock-out," i.e., the equipment shuts down and will not restart until a visit has been made to the sub-station. After the trouble has been corrected the lockout-relay may be reset. Overload on the A.C. side locks out the equipment because the inverse time relays are so set that ordinary overloads will be cleared by the D.C. breaker, and only a dangerous overload condition will operate the A.C. overload relays.

Conditions *c* and *k* are external to the plant; and if they revert to normal again the equipment is enabled to restart. Condition *b* is covered by the auto-reclosing gear and lock-out attachment "*l*," and by "*ac*" which will cause a lock-out if the D.C. overload persists.

Starting-Up.

The following describes, step by step, the functioning of the equipment from starting to shut-down. Reference should be made to the schematic diagrams in Figs. 6 and 7.

Provided all the protective items are in the normal positions, and the A.C. voltage is sufficiently high, then a start is possible. As soon as the D.C. voltage falls to the predetermined low value corresponding to the setting of relay *1*, and provided that it is not so abnormally low as to cause relay *80* to open its contacts, then time-delay relay *1X* will be energised from its auxiliary transformer.

After the time intervals of relay *1X* has elapsed the latter will cause master contactor *4* to close, which in turn will energise the oil-switch closing solenoid contactor *52X* and the total time relay *48*.

The oil-switch solenoid *52S* will now be energised, also relay *52Y*. The circuit breaker will close and relay *52Y* will cause the solenoid contactor *52X* to be de-energised and make it impossible for it to be re-energised except after a restart, thus preventing the solenoid from "hunting" should the breaker fail to become properly latched in. The main transformer and hence the anodes are now alive, and as several auxiliary contacts *52-4*, *52-5*, etc., on the oil-switch have closed, contactors *8X* and *95* have also closed, and all the auxiliary circuits are now energised from the auxiliary transformer.

The rotary vacuum pump starts up, the rectifier receives its excitation supply, the mercury vacuum pump heater starts to warm up, the grid-control synchronous motor runs up and comes into step with its field excited, and the grid bias metal rectifier is energised and excites the grids. The ignition anode dips into the mercury, and as the excitation arc is struck there is a potential at the rectifier terminals.

Meanwhile the contact-disc rocking motor has moved the disc to the low-voltage limit position. The value of this voltage is set so that it will be somewhat lower than the busbar voltage, and hence there is no tendency for the rectifier to seize the load the moment the D.C. breaker closes.

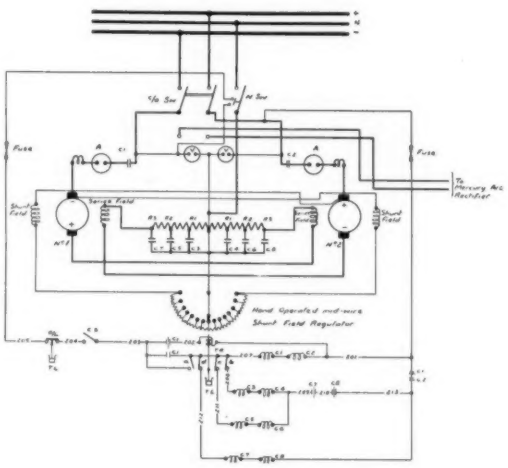
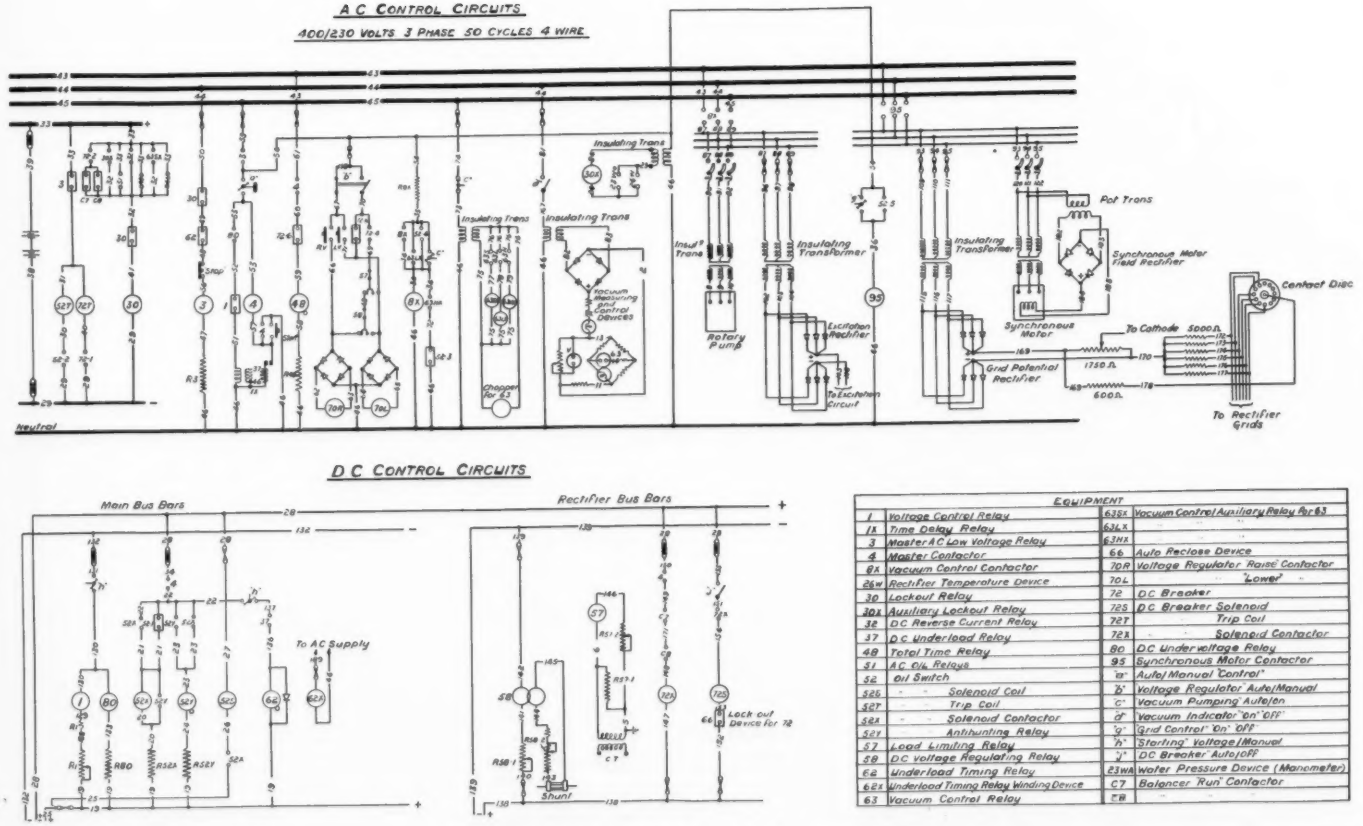


Fig. 6. Key Diagram of Rotary Balancer Circuits.

The balancer starting-time relay *T.R.* picks up when the rectifier is made alive on the D.C. side. As soon as relay *T.R.* picks up, it closes the balancer line contactors *C1* and *C2* which energise the balancer units through the starting resistance, de-energise *T.R.* and prepare circuits for the closing of contactors *C3*, *C4*, *C5*, *C6*,



EQUIPMENT			
1	Voltage Control Relay	63SX	Vacuum Control Auxiliary Relay for 63
1X	Time Delay Relay	63LX	" " " "
3	Master A.C. Low Voltage Relay	63HX	" " " "
4	Master Contactor	66	Auto Reclose Device
6X	Vacuum Control Contactor	70R	Voltage Regulator 'Raise' Contactor
26W	Rectifier Temperature Device	70L	" " 'Lower' "
30	Lockout Relay	7C	D.C. Breaker
30X	Auxiliary Lockout Relay	72S	D.C. Breaker Solenoid
32	D.C. Reverse Current Relay	72T	" Trip Coil
37	D.C. Underload Relay	72X	" Solenoid Contactor
48	Total Time Relay	80	D.C. Undervoltage Relay
51	A.C. Oil Relays	95	Synchronous Motor Contactor
52	Oil Switch	'a'	Auto/Manual Control"
52S	" Solenoid Coil	'b'	Voltage Regulator Auto/Manual
52T	" Trip Coil	'c'	Vacuum Pumping Auto/on
52X	" Solenoid Contactor	'd'	Vacuum Indicator "on" "Off"
52Y	" Antihunting Relay	'g'	Grid Control "On" Off"
57	Load Limiting Relay	'h'	'Starting' Voltage/Manual
58	D.C. Voltage Regulating Relay	'j'	D.C. Breaker 'Auto/Off'
62	Underload Timing Relay	23WA	Water Pressure Device (Manometer)
62X	Underload Timing Relay Winding Device	C7	Balancer 'Run' Contactor
63	Vacuum Control Relay	TB	" " "

Fig. 7. Key Diagram of A.C. and D.C. Control Circuits.

C7, and *C8*. The balancer now starts to rotate. Relay *T.R.* falls slowly against the resistance of an oil dash-pot and it closes, pair by pair, contactors *C3* and *C4*, *C5* and *C6*, and *C7* and *C8*. In this way the starting resistance is cut out step by step until finally the balancer is connected straight across the line and runs at full speed.

When the "running" contactors *C7* and *C8* close they cause the D.C. breaker solenoid contactor *72X* to be energised, which in turn energises the solenoid *72S* and the breaker *72* closes. The solenoid is then de-energised by a device attached to the breaker.

As the D.C. breaker closes, one auxiliary switch opens releasing the voltage-regulating gear from the impulse which has caused the disc to rotate to the minimum-voltage position. Another auxiliary switch closes, putting the voltage under the control of the voltage-regulating relay *58* and the load limiting relay *57*.

At the same time that the D.C. breaker *72* causes the voltage-regulating gear to come into action it de-energises the total time relay *48* to complete the starting sequence.

Voltage Regulation.

Voltage-regulating relay *58* has two exciting coils, one energised from the D.C. bars, and one connected in opposition to the former and energised from a shunt in the rectifier main connections. At no-load the first winding only is effective and allows the relay to balance only at the predetermined no-load voltage, the relay thus causes the contact disc to revolve until the no-load voltage is reached.

As the rectifier picks up load the winding connected to the shunt becomes energised and "bucks" the first winding, upsetting the balance of the relay, and in turn causing the voltage to be raised further in order to restore the balance. Thus, as the load rises the voltage rises also giving an over-compound characteristic to the rectifier.

Under certain conditions an over-compounded rectifier attempts to "seize" the available load. To prevent this the load-limiting relay *57* is included. This relay has its exciting coil connected to a current transformer included in the main A.C. circuit of the oil switch, and has its contacts so connected in the voltage-regulating circuits that should the load rise to the predetermined limiting value, it prevents the voltage-regulating relay *58* from raising the voltage any further. Should, however, the load still rise, due to some external cause, then the load-limiting relay will cause the contact disc to rotate so as to lower the voltage until sufficient load has been thrown off. When the severe load condition ceases the voltage-regulating relay takes over control.

The no-load value of voltage is adjustable by means of a rheostat as is also the percentage of over-compounding and the value at which the load will be limited. The voltage at which the rectifier will start up, and the current at which it will shut down, as well as the two corresponding time lags, are adjustable.

Shutting-Down.

When the load falls to the pre-set value, relay *37* energises the timing device *62*, the time lag of which is adjustable up to half an hour and incorporates an electrically-wound clock. The time-interval relay *62* opens its contacts which action in turn causes relay *3* to drop out. The opening of relay *3* causes both the oil switch and the D.C. breaker to trip and all auxiliary circuits to be de-energised. So that all items reset to the shut-down positions, after which *62* makes circuit and *3* picks up ready for a further start.

All necessary control switches and push buttons are provided, so that the equipment can be operated manually in cases of emergency or for testing purposes.

The Trolley Bus as a Public Service Vehicle.

Abstract of a Paper read before the Institute of Transport, Leeds,

By L. H. SHORT, M.C., A.M.I.E.E., A.M.Inst.T., Deputy Manager and Chief Engineer, Traction Department.

Some little time ago a report appeared in a North Country paper, covering an address by the Manager of a road transport undertaking. This Manager referred in his paper to the public service vehicle, and in doing so mentioned only the petrol-engined omnibus, forgetting that the various other forms of transport, in particular the suburban railways, the tramcar, and the trolley bus, can all substantiate the claim to be public service vehicles.

The purpose of this paper is to consider the trolley bus from this standpoint, and to show how its particular characteristics make it eminently suitable for town transport services.

In the first place a comparison is made between the trolley bus and the internal combustion engined vehicle, and then some account is given of certain new trolley vehicles which have been recently designed and built.

When making a comparison between the trolley bus and the petrol or oil-engined bus, we can consider it from various points of view; namely those of the passenger, the town dweller, and the operator, and it is proposed to deal with these three aspects in the order given.

Firstly the passenger from his point of view, the best vehicle is the one which provides him with the most rapid, frequent and comfortable travel. It can be accepted, and it is demonstrated later, that in city service where stops are frequent the trolley bus is capable of maintaining a higher schedule speed than the motor bus. With regard to frequency of service, the capacity of the trolley bus to maintain a higher schedule speed than is permitted by the motor bus, with a given number of vehicles, meets the passenger's second requirement of a more frequent service. With regard to the last feature of comfort, under this heading can be grouped a number of considerations.

In the first place the vehicle should be as silent as possible, and in this respect the trolley bus is distinctly superior to the motor bus. The electric motor and its transmission eliminate entirely all reciprocating parts, and in the trolley bus, therefore, there is an entire absence of vibration due to there being no imperfectly balanced reciprocating parts which are unavoidably present when internal combustion engines are used.

So far we have considered the noise which is produced by the vibration which accompanies reciprocating machinery. This, however, is not the only cause of noise in a motor bus. The gear box and clutch of even the most modern motor is silent only by comparison with the products of the past; it is also dependent on the skill and physical condition of the driver, and one of the features which particularly contributes to the quietness of the trolley bus is the absence of this mechanism.

We have considered vibration only in so far as it affects the noise, but vibration itself can be very objectionable. In the motor bus the greater part of the vibration arises from the gear box, and is particularly marked when the bus is travelling on the lower gears when starting or climbing hills.

Both noise and vibration are unpleasant from the passenger's point of view, and in these two respects the trolley bus is superior to the internal combustion engined motor bus. Another advantage which should be borne in mind, is that the trolley bus produces no fumes whatsoever, and is therefore entirely odourless. The exhaust fumes of the internal combustion engined motor bus, on the other hand, are a definite cause of discomfort, and although they are emitted at the rear of the vehicle, it is almost impossible to so design the exhaust system that fumes from the engine are entirely excluded from the interior of the vehicle.

So far we have dealt with the matter only from the aspect of the passengers. We will now see how the problem affects the citizen, whether as a passenger regularly using the service or otherwise. As a pedestrian or householder, the citizen naturally appreciates quiet in the road, and, as already pointed out, in this respect the trolley bus is preferable to the motor bus.

Fig. 1. "A.E.C.-English Electric" 60-seater Trolley Bus in service at Bournemouth.

The ordinary citizen has also a considerable interest in this matter both as regards the effect on the local rates, and the cost of electricity supply in the neighbourhood. It is well known that the cost of electrical energy depends very largely upon the consumption. Anything, therefore, which increases the consumption of electricity will reduce the price per unit to the citizen, and from this point of view a trolley bus system brings him an indirect advantage which would not be secured in the case of a motor bus service.

To illustrate the extent to which an electric traction system may influence the consumption of energy, the following representative figures taken from the Manual of Electrical Undertakings, September, 1932, for Municipal Systems where the traction loads form part of the Power Station load, may be of interest.

Expressing these figures as a percentage of traction load to total load, we find the following :

Town.	*Per cent. Traction Load to Total.*
Manchester	11.05
Liverpool	14
Birmingham	12.28
Nottingham	13
Bradford	20
Leeds	15.13
Edinburgh	15

It will be appreciated that if these considerable traction loads are eliminated by the substitution of petrol or oil vehicles, for tramcars, a considerable sum will be lost to ratepayers through installed plant and invested capital becoming idle. In the circumstance it is possible that an increased charge for lighting and power would be necessary to meet the increased overhead charges due to the reduction of load. Further the trolley bus consumes electricity produced by British coal, whilst the internal combustion engined vehicle depends on imported fuel. The production of fuel oil from coal in Great Britain is as yet in its infancy, and many years must elapse before it is produced in quantities which will affect the volume of imported fuel.

The trolley bus has been criticised on the grounds that it requires an unsightly overhead system. It is quite true that the poles and wires are necessary, but it should be remembered that in suburban districts the poles are required in any case for lighting purposes. High-powered street lighting requires substantial poles, and the tramway standards readily provide the supports for the street lamps. It is on record that in one provincial town famous for its amenities, one of the principal arguments of an eventually successful agitation to supersede the tramways was the unsightliness of the tramway standards. The system having been duly relinquished, it was found necessary for the Corporation to purchase

and retain the existing tramway poles to provide the supports for the street lighting.

From the operator's point of view the final criterion is first cost, operating and maintenance costs, and the total cost of operation, which includes the necessary charges to allow for depreciation and interest on capital. Detailed comparison between the operation of town and suburban services show that the trolley bus is definitely more economical than the petrol bus. The degree to which this is the case is shown on the curve in Fig. 3, which sets out the cost against density of service. This graph is based on statistics obtained from Garcke's Manual of Electrical Undertakings and the Motor Transport Year Book, both of September, 1933. They relate, therefore, approximately to the same periods. In both cases nine systems have been analysed, and four of these systems operate both trolley buses and petrol buses.

Petrol Buses—

Wolverhampton, Birmingham, Manchester, Bradford, Nottingham, Leeds, Portsmouth. Southampton, Halifax.

Trolley Buses—

Birmingham, Bradford, Nottingham, Wolverhampton, Chesterfield, Ipswich, Maidstone, Rotherham, Darlington.

Fig. 2. "A.E.C.-English Electric" 74-seater Trolley Bus in service in the Kingston District.

In selecting the nine systems cited, so far as trolley buses are concerned, they have been taken from those undertakings which supply sufficient data and costs to produce a detailed analysis. In the case of the petrol bus systems, these have been taken purposely to include both large and small undertakings, and have been spread over the country and not taken from a particular area only. The operating costs given are those covered by the items " Traffic," " Maintenance," " Management," " Taxes," and " Power," and do not include in either case " Interest on Capital " or " Depreciation." The operating cost figures, which are published on the basis of the bus mile, are of little comparative value owing to the varying seating capacities of the buses. To make the figures strictly comparable the operating costs have therefore been brought out to a figure of pence per 100 seat miles. As the revenue earning capacity of the vehicle bears a direct relation to the number of seats, this is the only fair comparative figure. The average of the operating costs per 100 seat miles for the nine trolley bus systems is 24.8d. whilst the corresponding figure for the petrol bus systems is 27.3d.

In order to arrive at a true comparative figure between a trolley bus system and a fleet of motor buses, it is necessary to add to the above operating costs the capital and depreciation charges. Unfortunately, it is practically impossible to analyse what these amount to for the different systems cited, partly to the lack of available information and partly owing to the different methods used by the respective concerns in arriving at their results. Figures have, therefore, to be derived from a knowledge of the average capital costs involved and the rate of depreciation to be allowed for.

In the case of petrol or oil-engined buses both the interest on capital and depreciation are directly proportional to the number of buses operating, but in the case of a trolley bus system these charges are dependent on the headway of the service, as well as the number of vehicles operating. This follows since the cost of the overhead line and other equipment external to the trolley buses depends more on the length of the route than on the number of buses in service. Consequently, the shorter the headway, i.e., the larger the number of buses per mile of route, the lower become the capital and depreciation charges per 100 seat miles operated.

The above considerations are reflected in the graph from which will be noticed that the total cost of operation per 100 seat miles is constant in the case of the petrol bus, but declines steadily in the case of the trolley bus as the headway is reduced. It will be seen, therefore, that the trolley bus shows up to the best advantage in the case of heavy town traffic.

Reference to the graph Fig. 3 shows that the costs of operation of the petrol and trolley bus balance when the headway is approximately 20 minutes. In plotting the graph it has been assumed that the schedule speed in the two cases are equal, but if we make allowance for the fact that the trolley bus is capable of operating at somewhat higher schedule speeds than the equivalent motor bus, the headway at which the cost of operation balances would be somewhat in excess of that shown. Assuming, however, equal schedule speeds, the graph shows that on financial grounds alone, the trolley bus system is the superior for all services where a frequency of, say, 20 minutes is justified by the volume of traffic ; that is for practically all town and suburban services. With a headway of 16 minutes the trolley bus shows an advantage over the petrol bus of rather less than 1d. per 100 seat miles. When the headway is reduced to 10 minutes the advantage is increased to over 2d. per 100 seat miles, and with a 5 minute headway the advantage is over 3d. per 100 seat miles.

Reverting again to the graph, it may be of interest to state the figures upon which the capital and depreciation charges have been based.

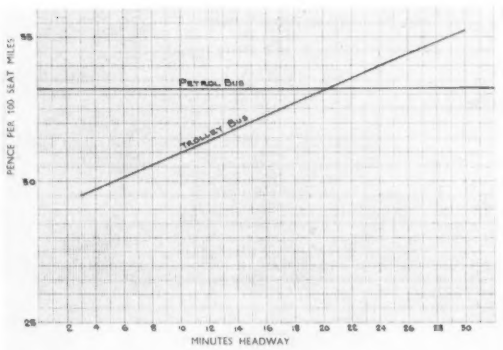


Fig. 3. Graph showing comparative operating costs in pence per 100 seat miles of the Petrol Bus and the Trolley Bus against density of service.

In the case of the trolley bus system, the vehicles are assumed to cost £1,800 each. The cost of the overhead line is taken to be £1,800 per mile of double track. Interest on capital is calculated at 4 per cent., depreciation on the overhead line at 5 per cent., and depreciation on the trolley vehicles at 10 per cent.

The corresponding costs for the petrol bus systems are—Cost of bus, £1,750, interest on capital, 4 per cent. ; depreciation on buses, 17 per cent. The capital costs given above are representative, and buses of equal seating capacity have been assumed.

It is hoped that the foregoing consideration of the relative merits of the trolley bus system as compared with the petrol bus will suffice to indicate that provided traffic conditions are suitable, the trolley bus is the most suitable public service vehicle. The graph also brings out the fact that the trolley bus system is cheaper than a fleet of petrol buses under town conditions, and indicates the point of demarcation where the internal combustion engined vehicle begins to justify itself.

A word should be said in respect to the motor bus equipped with a heavy-oil engine. The figures already given refer to a motor bus equipped with a petrol engine, and are not applicable to vehicles operating on heavy-oil fuel. There is an impression that the substitution of oil for petrol will bring about a very great reduction in operating costs owing to the very great difference in

the costs of these fuels. It will, however, be realised that any expectation of a drastic reduction of operating costs is extravagant when it is realised that the cost of the petrol alone for a petrol bus is only 2.43d. per bus mile. It is claimed that the corresponding fuel cost of the Diesel engine is .375d. per bus mile. Assuming this to be so, the maximum economy which is afforded by substituting a heavy-oil engine for a petrol engine is 2d. per bus mile. Such a saving, however, cannot be relied upon as it is necessary to set against it the admittedly higher, but as yet insufficiently established maintenance costs of the Diesel engine.

Another factor to be borne in mind in the cost of oil fuel, is that, the price at present is low although as the oil engine becomes more popular the price will have a tendency to increase. Another consideration bearing on the cost of the fuel is the incidence of taxation. At present petrol is taxed heavily, oil fuel lightly. Should there be, however, any general change of demand from petrol to oil in the future, it can hardly be doubted that the Government, faced with a loss of revenue on petrol, will increase the tax on oil fuel. All these considerations make the prospect of operating with oil fuel engines a matter of considerable hazard.

At the beginning of this paper the importance of a high schedule speed was referred to, and it was stated that in this respect the trolley bus is superior to the motor bus, owing to the higher average acceleration of which it is capable. From the point of view of the operator, the possibility of maintaining high schedule speeds is an attractive feature of the trolley bus in as much as it encourages passengers to use the vehicles and increases the revenue of the system.

There are two reasons for the superiority of the trolley bus in respect to acceleration. Firstly, the trolley bus draws power from an outside source, and is equipped with an electric motor having considerable overload capacity. Consequently, any amount of power within reason can be drawn upon during the acceleration period, and without difficulty or addition to the weight and cost of the equipment of the bus itself, or the system as a whole. The petrol or oil engined bus, on the other hand, carries its own prime mover, which has a strictly limited overload capacity, entailing a rapid falling off in the rate of acceleration as the speed of the vehicle increases. The only way to maintain a consistently high rate of acceleration throughout the acceleration period would be to increase the size, weight, and cost of the engine, and this, of course, is not an economic proposition.

The second reason for the superior acceleration of the trolley bus is the absence of gears. There is, therefore, no interruption in the acceleration such as inevitably occurs in a motor bus, whilst changing from one gear to another.

The graph in Fig. 4 shows the performance of an 11½ ton trolley bus when operating on a route with 8 stops to the mile. Allowing for stops of 10 seconds duration on the average, the trolley bus is easily capable of a schedule speed of 10 m.p.h.; retaining the same acceleration but omitting any coasting with power shut off, allows a schedule speed of 11 m.p.h. to be run.

In this graph the time in seconds is plotted

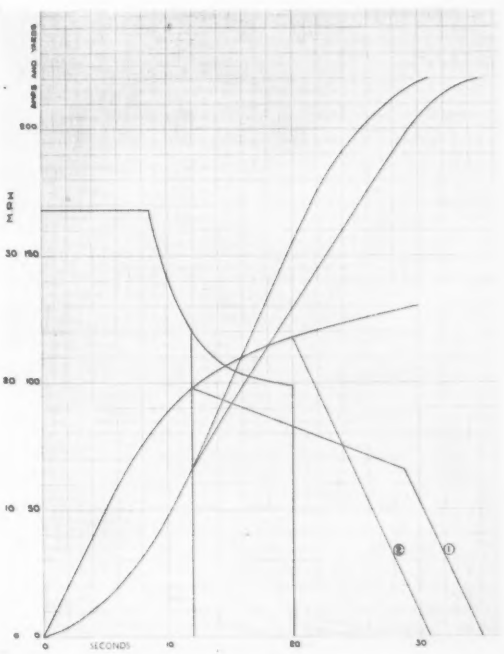


Fig. 4. Graph showing the performance of an 11½-ton Trolley Bus operating on a route with 8 stops to the mile.

horizontally, and the speed, distance and motor current vertically. The smooth uninterrupted acceleration of the vehicle is shown very clearly. Acceleration up to 10 m.p.h. is at the rate of 2 m.p.h. per second per second, whilst the average acceleration up to 20 m.p.h. is at the rate of 1.6 m.p.h. per second per second. During the acceleration period the vehicle absorbs power up to 84 kW. or 130 h.p., the normal continuous rating of the motor being of the order of 60 h.p.

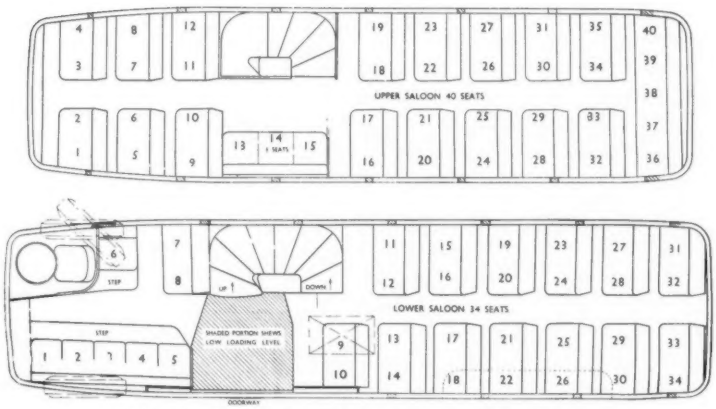


Fig. 5. Seating plan of the 74-seater Trolley Bus.

Another point of interest revealed by this graph is that the maximum speed attained by the bus when working a 10 m.p.h. schedule is something less than 20 m.p.h. and that, even when running without coasting, the speed does not exceed 24 m.p.h. It is evident, therefore, that a high maximum speed has very little influence on the schedule speed when a bus is operating in town service with frequent stops, the acceleration and deceleration determining the schedule speed. The characteristic of the electric motor gives the trolley bus a very definite advantage over the petrol bus in the former requirement.

Pursuing the claims of the trolley bus as a public service vehicle, it is now perhaps opportune to consider various types of modern vehicles. In the first place the trolley bus and the petrol or oil engined vehicle have a common parentage, and it is admitted that the former vehicle has tended to follow the development of the petrol bus. This is rather to be expected as the requirements of both types of vehicle, so far as service conditions are concerned, are the same. It is all the more interesting therefore to find that the trolley bus has progressed so far that a new vehicle has been designed and built by the Associated Equipment Company and the English Electric Company, and up to the present the vehicle has no counterpart in the form of a similar petrol engined vehicle. This new trolley bus is arranged to seat 74 passengers, and to provide additional standing accommodation. By careful design it has been possible to build the vehicle to come entirely within the standard limits of size and weight imposed by the Ministry of Transport. This vehicle has been designed to take the place, where necessary, of the high-capacity tramcar and contains a number of novel features.

The first feature is one of quick loading which has been achieved by the use of a central entrance, thereby reducing to a minimum the walking distance to all seats. A dropped frame of special construction is employed, which eliminates the necessity for a step and consequently speeds up loading and unloading. In order to safeguard passengers, the centre entrance is enclosed by air-operated sliding doors, which are under the control of the driver. The doors are interlocked with the control gear, and so arranged that until the doors are closed the driver cannot start his vehicle.

The driver of this vehicle is responsible for stopping and starting as he has control of the entrance, and this leaves the conductor free to attend to his other duties. From the seating plans shown in fig. 5 it will be seen that the whole of the space on both the upper and lower deck is usefully employed, and this is made possible by mounting the electrical control gear in cases on the chassis, whilst the single driving motor is mounted immediately behind the centre entrance and drives through only one short cardan shaft. The motor

is arranged with a four-point suspension carried on "silent-bloc" insulators.

The control equipment is either of the controlled series field type or regenerative type, and the brake equipment is of the straight air brake type. The air compressor is carried on the chassis side-member, and is also mounted on a "silent-bloc" suspension.

The "Q" type bus—this vehicle is of the latest design developed by the Associated Equipment Company, and is appearing both as a trolley bus and as an oil or petrol engined vehicle. As a trolley bus this vehicle, illustrated in the frontispiece, is built jointly by the Associated Equipment Company and the English Electric Company, and it is interesting to note that the "Q" type trolley bus will carry 63 seated passengers, see seating plan Fig. 6, whereas when supplied as a petrol or oil engined vehicle, in order to comply with the Ministry of Transport regulations, the seating capacity is three less.

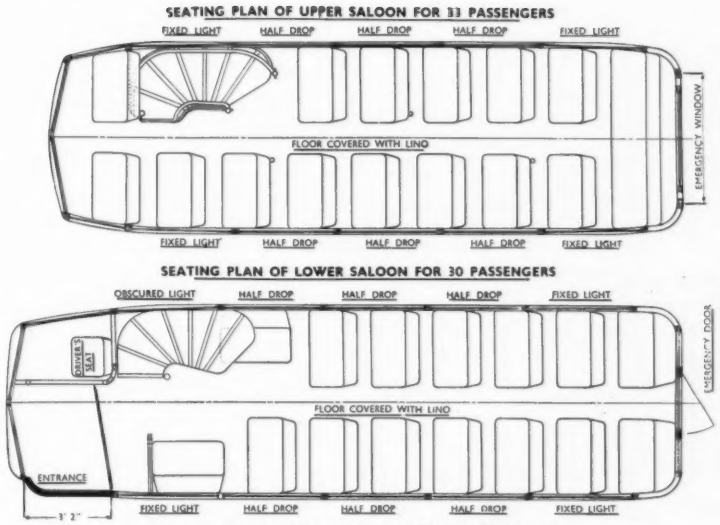


Fig. 6. Seating Plan of the "Q" type Trolley Bus.

The development of this bus is of interest as it will be seen that the front entrance and exit is right under the eye of the driver, and as in the 74-seater, the driver is responsible for the safety of the passengers alighting from and entering the vehicle, leaving the conductor to attend to collection of fares.

Steam Extraction Turbo-Alternator Plant.

Messrs. John Barker & Co., Ltd., Kensington.

The English Electric Company's contract covered the supply of the Turbo-Alternator Set, Control Panel, Condensing Plant and Cooling Tower.

There are several features of unusual interest in this plant. The plant is installed in the basement of a luxury stores, which is itself situated in the centre of a high-class residential district, and particular importance was attached to preserving the amenities not only of the building itself, but of the surrounding property also. It is of interest to mention that the Company were liable to heavy penalties in the event of Messrs. John Barker being the defendants in any civil action arising from the neglect of this consideration. The complete success of the plant in this respect is a tribute to the skill of "English Electric" design and manufacture.

In view of the foregoing conditions, it was necessary that the plant should run with the maximum amount of silence, and that there should be no transmission of vibration to any part of the building. To obtain this result the whole unit, comprising turbine, reduction gearing,

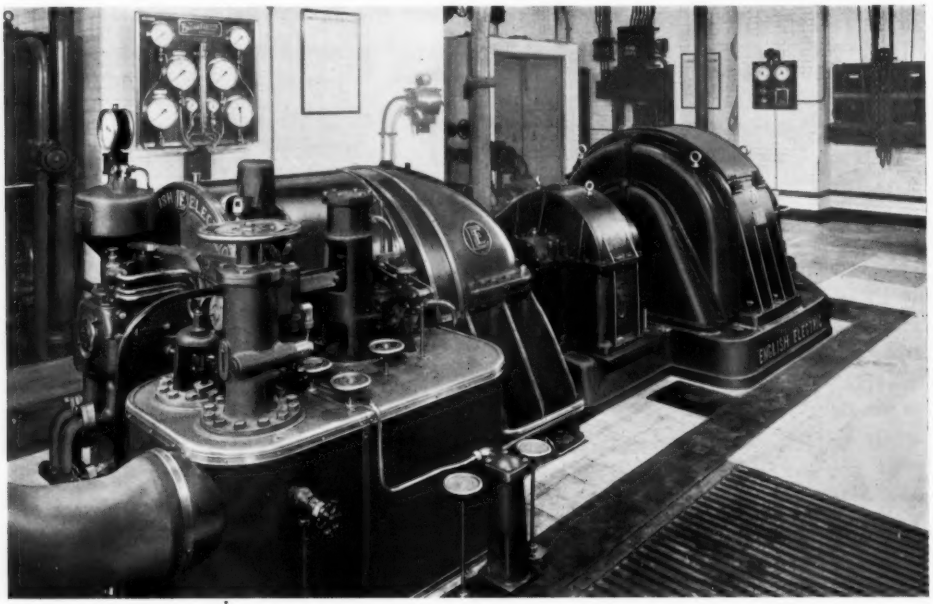


Fig. 1. The 837 kW. Pass-out Steam Turbo-Alternator Set at John Barker & Co., Ltd.

alternator and condenser, was mounted on a concrete raft, which was supported from the main foundation block by "Coresil" vibration-absorbing pads 2½ in. thick. The raft was otherwise entirely separated from the foundations, flooring and all parts of the building by an air gap, so that any vibration which might arise would be damped out before it reached the adjacent parts of the building structure. Further, the alternator was provided with a closed air cooling system, and is probably one of the smallest units extant which is so arranged.

In addition, the reduction gear, manufactured by the Power Plant Company, Limited, was fitted with a "Quill" drive on the pinion shaft, and particular care was taken in the cutting and running-in of the helical teeth. Provision was made so that, if necessary, the whole of the reduction gearing could be enclosed in a sound-absorbing blanket, but it has been found quite unnecessary to resort to this expedient.

In accordance with the Company's standard practice for high-speed machinery, the rotor of the turbine and alternator, were dynamically balanced in addition to the usual static balancing operations.

Prior to the installation of the turbo-generator all electrical power was purchased from the local Supply Authority on the basis of a two-part tariff, whilst steam for heating was supplied from high-pressure boilers through a reducing valve. A large amount of power is still purchased from the Supply Authority, but the turbo-generator, which runs in parallel with the Supply Authority's network, reduces the maximum demand on which the tariff is based, and therefore has the double advantage of very considerably lowering the cost of power purchased and relieving the Supply Authority's network at times of peak load. The high-pressure steam which previously passed through a reducing valve to the calorifiers in the building, is now passed through the turbine, so that the current generated by the plant is produced at a very low cost.

The turbine runs at a speed of 6,000 r.p.m., and is supplied with steam at 250 lbs. per square inch pressure, and total temperature of 625 deg. Fah. The maximum output is 865 kW., and under this condition 25,000 lbs. of steam per hour can be

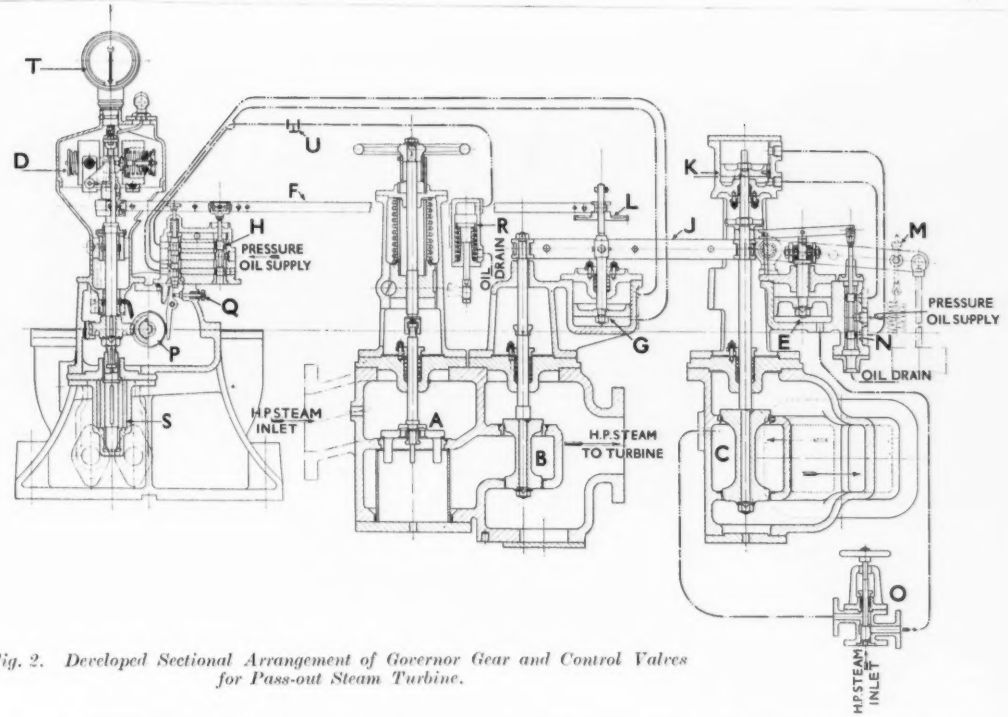


Fig. 2. Developed Sectional Arrangement of Governor Gear and Control Valves for Pass-out Steam Turbine.

A Stop and Emergency Valve for admitting High-Pressure Steam.

B Throttle Valve controlling High-Pressure Steam.

C Pass-through Valve admitting steam to low-pressure stages of turbine.

D Centrifugal Governor for controlling Turbine speed.

E Pressure Governor for controlling pass-out steam pressure.

F Floating Lever connecting centrifugal governor D to Relay Piston G and to Oil Distribution Valve H.

G Relay Piston and Cylinder operating Throttle Valve B and Pass-through Valve C.

H Distribution Valve supplying oil to Relay Cylinder G.

J Lever mechanically interlocking Relay Piston G to Throttle Valve B and Pass-through Valve C.

K Relay Piston directly coupled to Valve C and operated by Pressure Governor E.

L Speed Adjusting Gear, may be either hand or electrically operated.

M Pressure Adjusting Gear for Pass-out Steam.

N Distribution Valve supplying oil to Relay Cylinder of Pressure Governor.

O Starting-up Valve admitting High-Pressure Steam to underside of Pressure Governor Piston E.

P Overspeed Governor.

Q Emergency Hand Tripping Gear.

R Oil-operated Trip Piston for Stop and Emergency Valve A.

S Oil Pump, gear wheel type, delivers through distribution box to relay system and through pressure reducing valve to lubrication system.

T Double-faced Tachometer directly driven by the Governor Spindle.

U Branch to Trip Cylinder on Pass-out Steam Non-Return Valve.

passed out at a pressure of approximately 30 lbs. per square inch. The most economical output is 815 kW. when passing out 25,000 lbs. steam per hour, or 837 kW. when passing out 12,000 lbs. steam per hour.

The pass-out steam control gear is of the "English Electric" standard, mechanically interlocked type, details of which will be seen in Fig. 2. In this gear the main admission valve is mechanically interlocked with the pass-through valve, and the valves are designed to give a balanced steam flow under all conditions of working, so that no variation of speed occurs should the demand for heating steam rise or fall. Full details and descriptions of this gear are given in the Company's Publication No. 573A, together with particulars of other machines to which it has been fitted.

In view of the probability that, during the summer months the turbine would be standing idle for long periods, the blading and nozzles were made from stainless iron to eliminate corrosion which might otherwise occur.

The alternator is driven through the reduction gearing at 1,500 r.p.m., and is capable of producing 960 kVA. at 400 volts for short periods

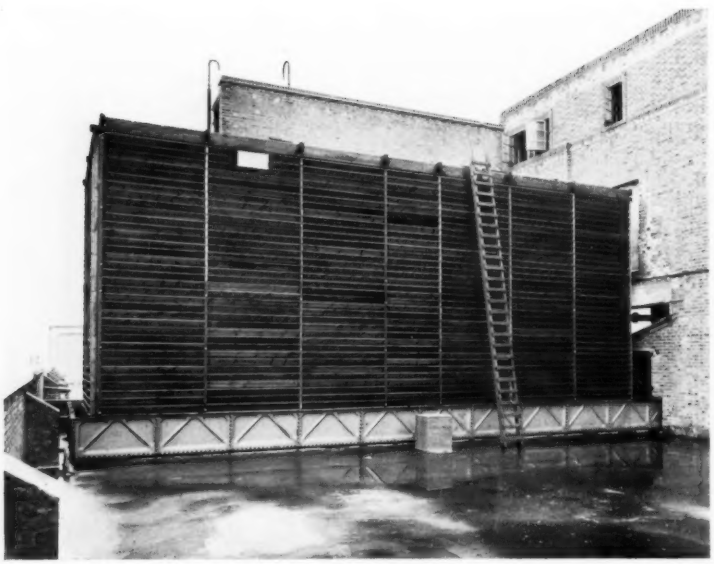


Fig. 3. The Atmospheric Cooler on Roof of Stores.

with a power factor of .95. It feeds direct into a four-wire ring main, which can be otherwise supplied from the 5,250-volt network of the Kensington and Knightsbridge Company through three 750 kVA. transformers mounted on the roof of the stores. A view of the generating plant is shown in Fig. 1.

Suitable protective devices are provided to safeguard the plant in the event of overloading, or a complete shut down of the outside supply. The alternator is controlled by means of an "English Electric" 1,500-ampere, 400-volt switchboard, fitted with the usual instruments and rotary synchroscope.

The condenser is of the surface type and was designed and manufactured by the English Electric Company. Here, again, special precautions to avoid the transmission of any vibration to the building were taken by supporting the condenser entirely from the turbine and dispensing with the usual spring supports. The cooling water for the condenser is circulated through a cooling tower, and the installation of this presented a problem inasmuch as the tower had to be placed on the roof of the store and so arranged that it would not present an unsightly appearance from the street. A compact form of atmospheric cooler made by the Premier Cooler & Engineering Co., Ltd., as illustrated in Fig. 3, was finally installed. Make-up water is obtained from the house service supply, which is pumped by a bore-

Fig. 4. Boiler Room showing Babcock & Wilcox Boilers.

hole pump driven by a 90 b.h.p. "English Electric" motor.

The boiler plant illustrated in Fig. 4 consists of four Babcock & Wilcox W.I.F. or longitudinal drum type of water-tube boiler, each of 2,700 sq. ft. of heating surface, with superheaters to deliver steam at 250 lbs. per sq. in. pressure and a final temperature of 625 deg. Fah.

Each of the boilers has four B. & W. pressure type oil burners served by a common B. & W. combined pumping and heating set, the latter comprising duplicate units so valved that each heater can be used with either pump or filter. The boilers are also fitted with Babcock Calorized Diamond Soot Blowers.

In the event of live steam from the boilers being required for heating, the steam passes through a reducing valve into a B. & W. de-superheater to reduce the temperature to just above saturation point at 30 lbs. per sq. in. pressure.

The plant was installed to the specifications of Mr. A. G. Freeborn, B.Sc., Chief Engineer to Messrs. John Barker & Co., Ltd., who was responsible for the layout of the complete installation.

200-h.p. Diesel-Electric Rail Coach.

Demonstration Run.

Fig. 1. Railway Officials and Representatives of the English Electric Company at the Diesel-Electric Rail Coach Demonstration.

Messrs. C. R. Byrom (*Chief Operating Manager, L.M.S.*), W. A. Stanier (*Chief Mechanical Engineer, L.M.S.*), Sir Harold Hartley (*Vice-President, L.M.S.*), H. N. Gresley (*Chief Mechanical Engineer, L.N.E.R.*), C. E. Fairburn (*Chief Engineer and Manager, Traction Department, English Electric Co.*), G. H. Nelson (*Chairman and Managing Director, English Electric Co.*), Sir Gerald Talbot and Mr. A. Winterbottom (*Directors of the English Electric Co.*).

Reference was made in the December, 1933, issue of this Journal to the 200-h.p. Diesel-electric coach which has been operating during the past five or six months on the L.M.S. Railway. An

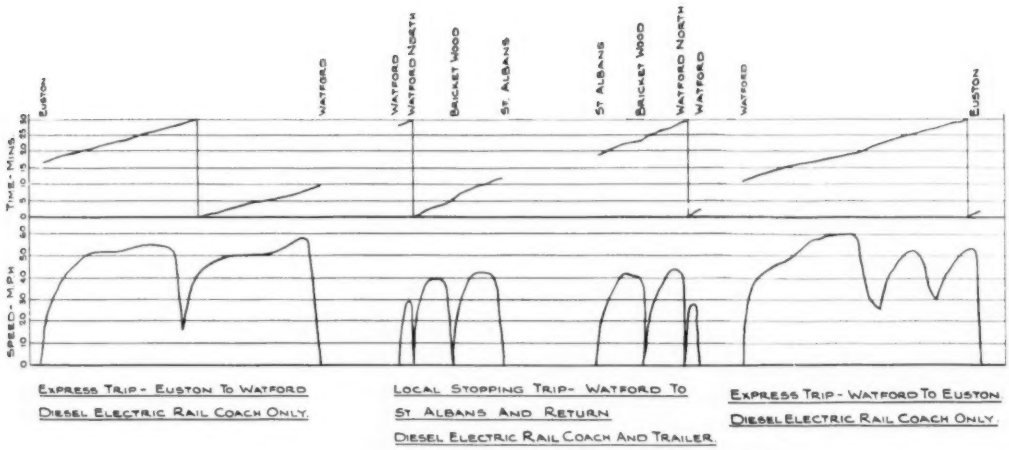


Fig. 2. Teloc Chart recording progress of Demonstration Run.

opportunity was taken on the 26th January to invite a number of the L.M.S. Railway officials and other leading railway and consulting engineers to take part in a demonstration run. In order to show the capabilities of the coach, the following journey was made :—

The coach left Euston, running as a single unit, with the party on board, and made a non-stop run on the fast line from Euston to Watford Junction. At Watford the rail coach was coupled to a standard trailer coach and a stopping run was then made from Watford to St. Albans, and return, this stopping run being over the same route and to the same timings as for the normal service which the rail coach and trailer had been previously carrying out. On the return to Watford the trailer coach was then uncoupled and a fast run was made from Watford to Euston. During the run from Watford to Euston Mr. W. A. Stanier, Chief Mechanical Engineer, L.M.S., drove the rail coach, and as will be seen from the Teloc curves, Fig. 2, a speed of 60 m.p.h. was reached.

As a matter of interest, particulars of the performance of the vehicle during five representative weeks on the Watford-St. Albans branch line are here given. The rail coach is now in service in the Derby district, where it is running on the Burton-Tutbury branch line.

RUNNING DATA. WATORD-ST. ALBANS SERVICE.

Date, Week ending	Miles run (with Trailer).	Approx. Total, ton miles.	Engine Fuel Oil, gallons.	Boiler Fuel Oil, gallons.	Total Fuel, gallons.	Engine Fuel, miles per gallon.	All Fuel, miles per gallon.	Engine Fuel, lbs./ton mile.
23/12/33	874.5	60,000	237.7	105	342.7	3.68	2.55	.0344
30/12/33	885.5	61,000	245.2	85	330.2	3.61	2.68	.0347
6/1/34	826.0	57,000	239.2	77	316.2	3.44	2.62	.0360
13/1/34	863.0	59,000	236.6	74	310.6	3.65	2.78	.0347
20/1/34	861.0	59,000	232.4	70	302.4	3.72	2.85	.0340

On this service the rail coach was permanently coupled to a standard trailer coach.
Total mileage run, including above, 15,000. Consumption of lubricating oil, one gallon per approximately 250 miles.

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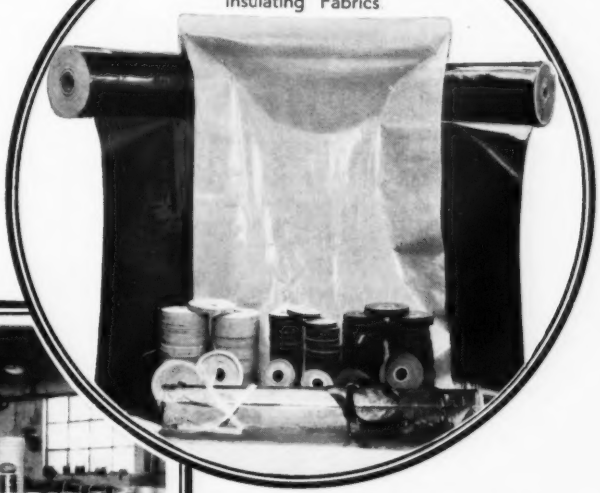

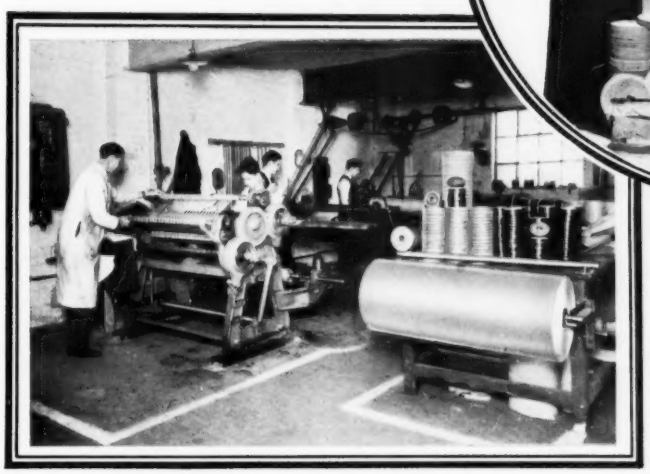

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	I.D.	Wall Thickness.	k.V.	v/mil.	k.V.	v/mil.
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	2"	0.128	61	476	63	492

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	Results obtained at 90° C.		
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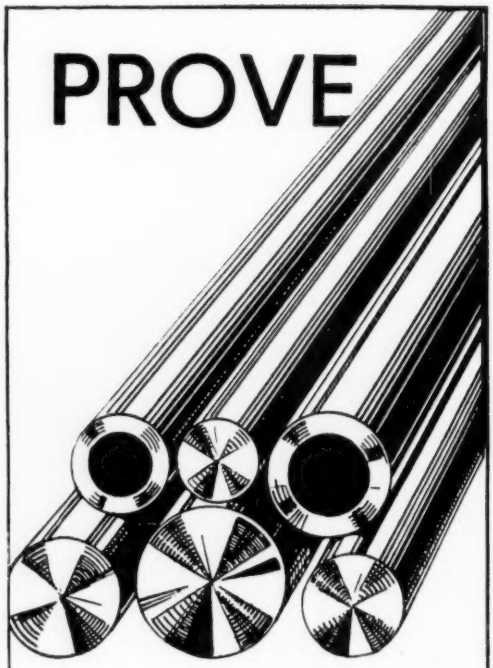

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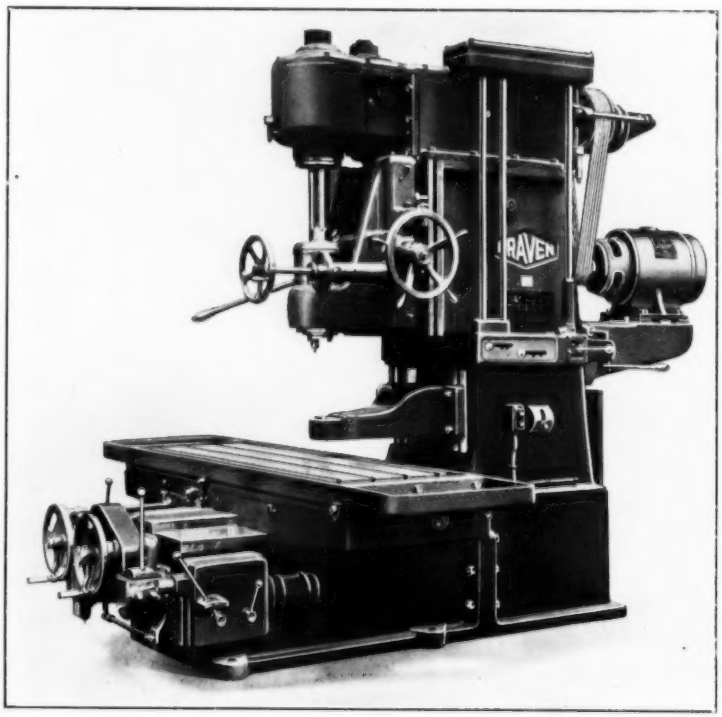

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Asquith, William, Ltd. XIII
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Attwater & Sons X
Bolton, Thomas & Sons Ltd. XII
Broadbent, Thos. & Sons, Ltd. III
Craven Brothers (Manchester), Ltd. XIV
English Electric Company Limited I, V, XII
Hall Bros. (West Bromwich) Ltd. X
London Electric Wire Co. & Smiths Ltd. XV
Mason, E. N., & Sons, Ltd..... XI
Micanite & Insulators Co., Ltd. IX
Midland Steel Co., Ltd. VI
Siemens Brothers & Co., Ltd. VIII
Silvertown Lubricants Ltd. VII
Straker Brothers Ltd. XVI
Taylor, Tunnicliff & Co., Ltd. VI
Tube Products Ltd. II
Walker, James & Co., Ltd..... V
Westinghouse Brake & Saxby Signal Co., Ltd. II

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